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Emotional Facial Activation induced by Unconsciously Perceived Dynamic Facial Expressions

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Abstract

Do facial expressions of emotion influence us when not consciously perceived? Methods to investigate this question have typically relied on brief presentation of static images. In contrast, real facial expressions are dynamic and unfold over several seconds. Recent studies demonstrate that gaze contingent crowding (GCC) can block awareness of dynamic expressions while still inducing behavioural priming effects. The current experiment tested for the first time whether dynamic facial expressions presented using this method can induce unconscious facial activation. Videos of dynamic happy and angry expressions were presented outside participants' conscious awareness while EMG measurements captured activation of the zygomaticus major (active when smiling) and the corrugator supercilii (active when frowning). Forced-choice classification of expressions confirmed they were not consciously perceived, while EMG revealed significant differential activation of facial muscles consistent with the expressions presented. This successful demonstration opens new avenues for research examining the unconscious emotional influences of facial expressions.

Key words: Electromyography; Facial Expressions; Emotion; Nonconscious Processing

Introduction

Facial expressions of emotion are an important part of human social interaction – so important that human beings have evolved the ability to process such expressions both extremely quickly and automatically. It is now generally accepted that an emotional face can impact an observer even when he or she is not aware of its presence (e.g. Tamietto & de Gelder, 2010). For example, previous studies have found that even in the absence of conscious recognition, emotional expressions influence participants' evaluative decisions (e.g. Almeida, Pajtas, Mahon, Nakayama, & Caramazza, 2013; Murphy & Zajonc, 1993), activate affect-related brain regions such as the amygdala (Whalen et al., 1998) and lead to emotion-congruent reactions in participants' own facial muscles (Dimberg, Thunberg, & Elmehed, 2000). Overall, measuring the impact that unconsciously perceived facial expressions have on an observer can help to elucidate the automatic aspects of face processing and disentangle such effects from more conscious, strategic reactions towards others' expressions. While several approaches for blocking visual awareness exist, they all constrain the type of stimuli that can be employed (for a review of several techniques see Kim & Blake, 2005). To date, the most commonly utilized method for blocking awareness of facial stimuli has been visual backward masking. Here, the presentation of an emotional face is immediately followed by a non-emotional picture (e.g. a photo of a neutral expression) which helps to block the awareness of the main stimulus of interest (see Kouider & Dehaene, 2007). Crucially, preventing awareness in this way is only possible if the emotional face is presented for a very short time, usually 10 to 30 milliseconds. This constraint on the duration of exposure usually limits experimental studies of nonconscious face processing to the use of static facial images.

In contrast to the static images used in back-masking studies the facial expressions we experience in everyday life are dynamic, i.e. we usually encounter movements of facial muscles that can unfold and change over several seconds. Importantly, a growing body of evidence suggests that the movement and timing of an expression might play a role in how we process it in both quantitative and qualitative terms. Quantitatively, previous studies have found that consciously viewed dynamic facial expressions, as compared to their static counterparts, are rated as more intense (Biele & Grabowska, 2006), create stronger activation in brain regions associated with the processing of socially relevant stimuli (Arsalidou, Morris, & Taylor, 2011), and lead to stronger facial reactions in the observer (Sato, Fujimura, & Suzuki, 2008). Qualitatively, some experimental evidence suggests that people rely on the timing of an expression to interpret its meaning (Ambadar, Schooler, & Cohn, 2005), for example when distinguishing between authentic and posed displays of emotion (Sato & Yoshikawa, 2004; Krumhuber & Kappas, 2005). This raises the question as to whether the influences of dynamic aspects of expressions are dependent on their conscious appreciation or can also result from nonconscious processing. A paradigm permitting effective nonconscious processing of dynamic expressions would help to increase the ecological validity of future experimental findings (Krumhuber, Kappas, & Manstead, 2013). Additionally, it would open new research avenues such as exploring the unconscious influence of changes in expression, for example from an expression indicating happiness to one of anger or disgust.

Sato, Kubota, & Toichi (2014) presented an approach to address this limitation within the backward masking paradigm by showing three photos in quick succession (presenting an expression at its onset, its midlevel, and its peak), which were then masked by a neutral stimulus. This effectively results in a short backward masked stop-motion animation. While this presents an improvement in terms of being able to employ dynamic face stimuli in unconscious presentations, the reliance on backward masking here still limits the possible face animation duration (~30 ms in Sato et al., 2014). The resulting need to rely on a stop motion animation of only three pictures produces stimuli that are still arguably different in richness to a natural, dynamic display of emotions.

A recent alternative approach to presenting facial expressions outside of awareness has been described by Kouider, Berthet, & Faivre (2011), who used the gaze contingent crowding paradigm (GCC) to prevent the awareness of videos of facial expressions. In their study dynamic happy and angry faces were shown parafoveally, i.e. in the periphery of people's viewing field, in such a way that participants were not able to focus on the videos directly. These expressions were surrounded by unrelated objects ('flankers') at close proximity giving rise to the so-called crowding effect – the phenomenon that objects close to each other in peripheral vision are perceived as blurring together, making the identification of the crucial face stimuli substantially harder (Levi, 2008). The advantage of preventing awareness using this method is that it is not directly dependent on the duration of the target stimulus; it thus permits the presentation of naturally unfolding dynamic expressions over several seconds. It was found that, despite being unable to consciously identify the expressions being presented, participants rated Chinese characters presented after happy faces as more positive than after angry ones. While these previous studies found evidence that crowded nonconscious presentation can elicit behavioral priming, the current experiment tested for the first time if this technique can be used to induce mirrored facial reactions in the observer. More specifically, we tested if nonconsciously presented happy versus angry faces lead to more smiling (activity in the zygomaticus major muscle) and less frowning (corrugator supercilii muscle, cf. Dimberg et al., 2001).

We also retain the measure of behavioural priming used in previous studies by having participants rate an ambiguous stimulus (Chinese symbol) after each video. This could shed light on a possible interplay between bodily and behavioral priming effects. It is often assumed that these two different aspects of emotional reactivity are closely interrelated, with some theories of embodiment even proposing that a bodily reaction towards a stimulus such as a change in facial expression can causally influence evaluative decisions (Winkielman, Niedenthal, Wielgosz, Eelen, & Kavanagh, 2015; McIntosh, 1996). More specifically, it has been assumed that one's own facial activation can influence evaluative decisions via so-called facial feedback (e.g. that more frowning activation would be related to more negative ratings; cf. Larsen, Kasimatis, & Frey, 1992). If such accounts were true, one would expect to find a relationship between a participant's facial reaction and rating tendency, in a way that a higher degree of smiling/frowning would predict a more positive/negative rating.

Overall, the current study combines the GCC paradigm with EMG measurements of facial muscle activation for the first time in order to evaluate the extent to which unconscious facial activation can be induced via this method. If dynamic expressions presented using GCC are capable of inducing facial activation we should observe a pattern of less frowning (corrugator supercilii activation) and more smiling (zygomaticus major activation) during the presentation of happy as compared to angry expression videos. By asking participants to rate an ambiguous target stimulus directly after each prime video, we also tested if any induced change in smiling/frowning activation would leads to a subsequent behavioral effect, i.e. more positive/negative evaluations.

Method

Participants

Participants were 111 students (70 female) from the University of Sussex. All participants reported corrected-to-normal vision and had no prior knowledge of the Chinese characters used for test stimuli. Since preliminary analysis of the EMG data revealed that three participants showed average activation more than 2.5 standard deviations above the mean of the sample, these were treated as outliers and excluded from the final analysis, resulting in a sample of 108 students with a mean age of 27.77 (SD = 10.18). Based on previous EMG experiments we anticipated a small to medium effect size. We therefore utilised GPower to conduct an a priori power analysis for a repeated measures between factor ANOVA with a medium effect size (f = 0.25). This indicated that the total sample size required to achieve a power of 0.8 was 98. We sought to exceed this target, hoping to recruit 110 participants anticipating a number of exclusions and recognising that a medium effect was on the optimistic side.

Materials

Face stimuli comprised of 16 video clips (taken from Kouider et al., 2011), each showing the face of one of eight actors performing either a happy or angry expression. Each clip lasted for 2.5 s, whereby in the first second each actor showed a neutral expression, followed by the enactment of the happy or angry expression during the next 0.5 s, which was then maintained at peak intensity for the last second. In order to facilitate the crowding effect, 45 non-informative, quasi-random patterns were employed as flankers around the face stimuli. These flankers had a similar size and oval shape as the faces in the videos. For testing the effect of the face presentations on subsequent evaluations, 80 Chinese characters were taken from an internet database (http://en.glyphwiki.org/), each consisting of the same number of brush strokes. All stimuli were presented in greyscale against a black background on a 21” Dell Trinitron P1130 monitor with a refresh rate of 85 Hz and a screen resolution of 1280 X 1024 pixels.

Eye gaze was measured via a head-mounted SR Research Eyelink II eye tracker with a sampling rate of 250 Hz and a spatial resolution of 0.01˚. Facial EMG was measured with pairs of 4-mm AG/AG-Cl touch-proof electrodes filled with conductive paste (Biopac GEL 100). Prior to electrode attachment, participants’ skin was cleaned with Nuprep skin preparation gel in order to reduce resistance. Electrodes were then placed on the regions of interest according to the recommendations of Fridlund & Cacioppo (1986). The signal was recorded via a Biopac MP36 measurement unit at a sample rate of 2000 Hz.

Procedure

Participants were seated with a chin rest at a distance of 54 cm from the display. Since it has been suggested that performing a motor action can increase the sensitivity to observations of similar actions (Schütz-Bosbach & Prinz, 2007), the experiment started with a conscious observation and imitation task of the facial expression stimuli. More specifically, all videos were presented in the centre of the screen twice in randomized order and participants asked to imitate the expressions they saw. It was hypothesized that such a conscious imitation might help to facilitate muscle activation in the ensuing unconscious presentation of the videos.

The main part of the experiment consisted of parafoveal, crowded displays of the expression videos. Each trial started with a white fixation cross (approx. size: 1˚ width × 1˚ height) appearing towards the top of the screen. Participants were instructed to focus on this cross at all times. After one second, while the fixation cross remained present, one of the videos (3.2° x 3.8°) appeared towards the bottom of the screen surrounded by six randomly chosen flankers (3° x 3°; 3.2°centre to centre eccentricity between face and flankers). The video presentation lasted for 2.5 seconds. During the trials participants' gaze position was measured via an eye tracker. Whenever their point of fixation deviated from the fixation cross by more than 5°, the video was replaced by an upward arrow. This approach ensured that test subjects could not identify the videos by directly focusing on them. Participants were told that if they saw the arrow they should treat it as a reminder to remain focused on the fixation cross. The GCC procedure consisted of three separate phases: Awareness threshold detection, priming phase and post-experiment awareness test.

The awareness threshold detection determined the distance between fixation cross and video individually for each participant. Larger distances should make it harder to consciously identify the stimuli. Thus, the goal was to determine a fixation-video distance that was as close as possible to a participant's central viewing field, but far enough away to block conscious expression identification. Our procedure sought to identify the subjective threshold of unconscious awareness i.e. that threshold where participants are not conscious of being able to distinguish between stimuli, irrespective of objective performance (Cheesman & Merikle, 1986).

After each video presentation, participants had to indicate a) whether the face presented was either smiling or frowning and b) whether they were either "at least a bit confident" in their answer or were "just guessing" the expression (a measure of their subjective awareness). If a participant reported at least some confidence in their ability to see an expression and identified it correctly, the distance between prime and fixation cross was increased for all subsequent trials. Where a participant reported just guessing the answer (i.e. having no subjective awareness) or did not correctly identify the face, the next trial used the same fixation-prime distance. This procedure continued until a participant reported no subjective awareness on eight consecutive trials. The so-determined fixation-video distance was employed in the remainder of the experiment, with a post-experiment awareness test (see below) used to confirm its effectiveness after the experimental trials.

The priming phase was used to measure the behavioural and bodily priming effect of the crowded videos. Facial EMG measurements during the video presentations were used to assess the influence of the video type on muscle activity. In order to measure behavioural effects, a Chinese character ($2.8^\circ \times 3.5^\circ$) appeared in the position of the fixation cross for 150 ms immediately after the end of each video presentation. On a subsequent screen participants were asked to rate the pleasantness of this character on a 4-point scale (1 = *rather unpleasant*; 4 = *very pleasant*). Overall, there were 80 prime trials with each of the characters being presented once and each of the prime videos five times. The order of the characters, the prime videos, and the assignment of videos to the Chinese symbols was randomized for each participant.

The post-experiment awareness test assessed participants' subjective awareness at the fixation-video distance determined at the start of the study. This test was administered after the main priming phase to confirm that the threshold distance required for unconscious exposure had not altered during testing. The task was identical to the one in the threshold identification phase, i.e. participants were asked to identify the face and to indicate if their answer was based on at least some confidence or was a complete guess, with the only difference being that the fixation-video distance was kept constantly at the level used during the main priming phase. This test lasted for 32 trials, with each of the prime faces being presented twice in randomized order.

Data Pre-processing

In order to obtain an objective measure of task adherence, the percentage of time that a participant kept their gaze on the fixation cross was evaluated for each trial. Since the prime videos were removed from the screen whenever participants did not look at the cross (and hence no priming was possible a priori), we excluded all trials from the data analysis where participants' gaze deviated from the intended point of fixation for more than half of the trial length (3.72 % of all trials).

Concerning the EMG, after filtering the signal (high pass: 5 Hz, low pass: 500 Hz) in order to attenuate noise artefacts, the signal was then treated to a moving-average integrator with a window size of 100 samples. For each trial of the priming phase, the average activity of each muscle site in the last 1000 ms was calculated; only in this period were the video facial expressions fully developed. These values were then baseline-corrected by subtracting the mean activation of the one second prior to stimulus onset. The resulting change scores were transformed to z-scores for each participant. Hence, the final values express the degree of change in muscle activation during each trial, relative to the average change in activity in all of a participant's trials. In order to account for anomalies due, for example, to movement artefacts, trials with z-scores higher than 2.5 were excluded from the final analysis (2.43 % of all trials).

Results

Effectiveness of Awareness Prevention

The procedure for adjusting the distance between fixation cross and prime video resulted in centre-to-centre distance in pixels of M = 746.52 (24.1 ˚), SD =125.54 (4.1 ˚). To test for the presence of subjective awareness of the parafoveal expressions we employed the zero-correlation criterion of unconscious knowledge (Dienes, 2007). This criterion evaluates the relationship between confidence and accuracy and asserts that where accuracy is no greater in the presence versus absence of confidence then any knowledge employed to make the judgement was unconscious. This criterion was clearly fulfilled in our data; the percentage of correct responses for judgments made with confidence (M = 50.10, SD = 0.40) was both non-significantly different from chance performance (50%), $t(107) = 0.03$, $p = .98$, $d < .01$, and non-significantly different from the percentage correct when reporting guessing (M = 54.65, SD = 0.13), $t(107) = -1.25$, $p = .21$, $d = .13$. Accuracy when reporting confidence was in fact slightly *lower* than when reporting guessing. Thus our participants demonstrated no conscious awareness of the nature of the different expressions.

Influence of Unconscious Expressions on Facial Activation

The mean and standard error of participants' facial reactions towards the videos are shown in Figure 1. In order to test the effects of the expression primes on participants' facial activity a 2 (muscle: zygomaticus/corrugator) by 2 (prime type: happy/angry) repeated measures ANOVA was conducted. Results revealed no significant main effect of muscle group, $F(1, 107) = 1.59$, $MSE = .011$, $p = .21$, $\eta_p^2 = .02$, or prime type, $F(1, 107) = 0.78$, $MSE = .012$, $p = .38$, $\eta_p^2 = .01$. Importantly, there was a significant muscle x prime interaction, $F(1, 107) = 7.20$, $MSE = .009$, $p = .008$, $\eta_p^2 = .06$, indicating that the smiling and frowning muscles were affected differently by the two video types. In order to explore this interaction, the effects of prime type were calculated for each muscle individually. For the corrugator muscle, angry video primes produced significantly more activation than happy videos, $t(107) = 2.15$, $p = .03$, $d = .21$. For the zygomaticus muscle, a difference in the opposite direction (i.e. more smiling in response to happy than to angry videos) was observed but failed to achieve significance, $t(107) = -1.40$, $p = .17$, $d = .13$. Thus the unconsciously perceived videos of dynamic facial expressions reliably induced emotional facial activation.

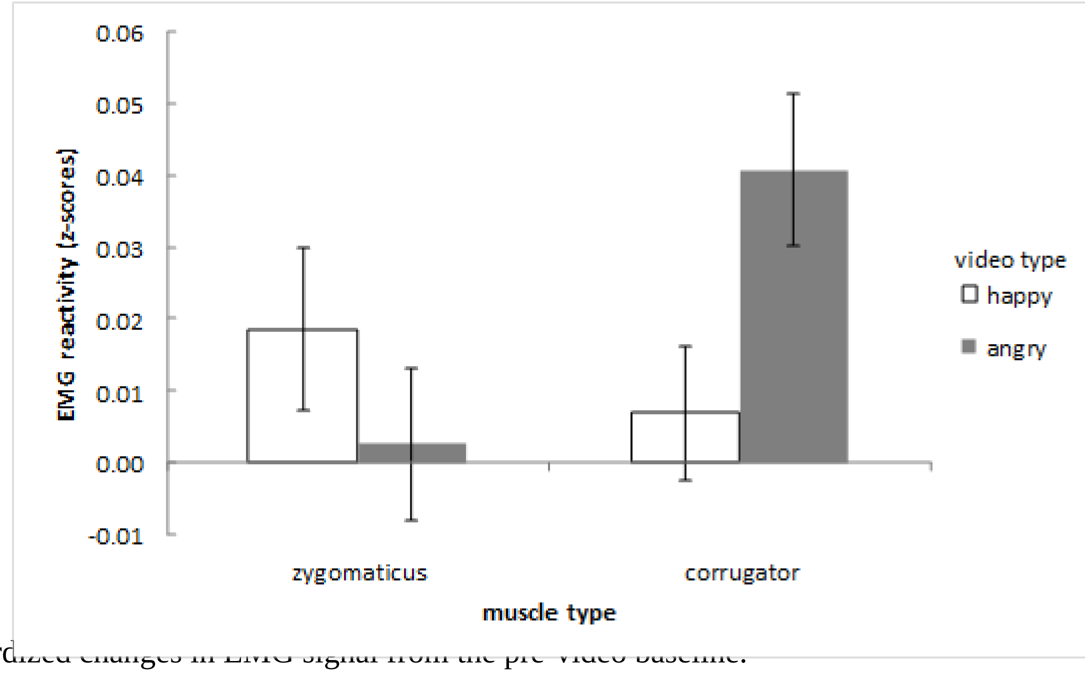

Figure … nt

standard… changes in EMG signal from the pre-video baseline.

Influence of Unconscious Expressions on Character Ratings

The effect of the prime videos on the ratings of the Chinese symbols was tested by comparing participants' average ratings for characters shown after happy videos (*M* = 2.63, *SD* = 0.39) with the average ratings after angry videos (*M* = 2.62, *SD* = 0.37). No significant difference was found, $t(107) = 0.39$, $p = .70$, $d = .04$. Given our failure to replicate the behavioural effect previously observed (e.g. Kouider et al. 2011) it is important to establish whether the present negative finding represents strong evidence against the behavioural influence or could be due to statistical insensitivity; a Bayes Factor was therefore computed. Adopting the procedure advocated by Dienes (2011), the alternative hypothesis was modelled as the difference between pleasantness ratings after happy versus angry primes based on the difference in proportion of pleasant versus unpleasant ratings observed by Kouider et al. (7%). A Bayes Factor of less than one-third is the recommended threshold for interpreting nonsignificant findings as substantial evidence for the null-hypothesis (cf. Dienes, 2011). The resulting Bayes Factor was 0.5, thus prevents strong conclusions regarding the failure to observe a behavioural effect in this instance. In order to see if changes in facial reactions predicted the ratings, we conducted a multiple regression analysis with zygomaticus activation, and corrugator activation predicting character ratings. As the data is nested, with 80 trials within each of 108 participants, we employed a multilevel model using a sandwich estimator in Mplus version 6 to take account of the clustering. The analysis revealed that neither zygomaticus activation ($\beta = .010$, $p = .37$), nor corrugator activation ($\beta = .016$, $p = .30$), significantly contributed to the model. Overall, muscle activation was unable to account for any of the variance in character ratings; $R^2 < 0.001$, $SE = 0.001$, $p = 0.44$. This indicates that participants' character evaluations were not related to their facial muscle activity.

Discussion

This study employed the gaze contingent crowding paradigm (GCC) in order to present dynamic happy and angry facial expressions to participants without awareness. For the first time we investigated if this technique is capable of inducing emotion-congruent facial reactions in the zygomaticus ('smiling') and corrugator ('frowning') muscles. Results indicated that participants' muscles showed a differential response towards the videos that was in line with the assumption that nonconsciously presented primes can evoke facial muscle responses. The effect was most pronounced for the corrugator muscle, which showed significantly more activation during the presentation of angry as opposed to happy expressions, while the zygomaticus showed the opposite pattern of activation without individually achieving significance. The weaker effect for the zygomaticus is consistent with studies that found less pronounced differentiations between positive and negative affect for the zygomaticus than the corrugator muscle (Larsen et al., 2003), while other publications report stronger effects for the zygomaticus (Moody & McIntosh, 2011). Since upper and lower face muscles are partly innervated by different brain regions (Adolphs, 2002), it would be worth investigating if these results indicate that reactivity of these muscles are mediated by different processes.

Finding nonconscious emotional facial activation with the GCC technique supports the view that unconscious facial reactivity is a general feature of visual processing, and not just limited to individual procedures used to block conscious processing (e.g. backward masking, cf. Dimberg et al., 2000). The demonstrated effectiveness of this paradigm creates an exciting opportunity to more fully explore the unconscious influence of dynamic expressions and transitions between them.

While the nonconscious face primes had a significant influence on facial muscle activation, their influence on affective ratings of the subsequently presented Chinese characters did not achieve significance. Despite a substantial sample size (N = 108) the Bayes factor revealed these analyses to lack sensitivity and hence we cannot draw strong conclusions regarding the failure to observe these effects. Several studies present evidence either for the possibility of nonconscious face presentations to either influence bodily responses (Bailey & Henry, 2009; Dimberg, Thunberg, & Elmehed, 2000) or evaluative decision-making (Murphy & Zajonc, 1993) on their own. Since embodiment theories of emotion propose that evaluative decisions can be influenced by the state of one's facial muscles via proprioceptive feedback (e.g. Davis, Senghas, & Ochsner, 2009; Larsen et al., 1992), it would be of great interest to better understand the relation between these factors in nonconscious priming. On the one hand, Foroni & Semin (2011) found that nonconscious emotional faces ceased to influence subsequent behavioural evaluations when participants were asked to press their lips together, resulting in continuous muscular interference. On the other hand, in line with the current results Rotteveel, de Groot, Geutskens, & Phaf (2001; Exp. 2) found facial reactions towards nonconscious emotional faces (using backward masking) but no influence on subsequent ratings of ambiguous stimuli. Note that both

Rotteveel et al. (2001) as well as the current study relied on EMG measurement of naturally-occurring facial activation (which tends to be very subtle, cf. Tassinary & Cacioppo, 1992), while Foroni & Semin (2011) employed artificially-induced, comparatively strong muscle tension. Thus, it might be possible that muscle activation needs to reach a certain level of intensity before it can influence the behavioural consequences of a nonconscious priming procedure.

Overall, looking into approaches to increase the impact of parafoveal primes might lead to both a higher chance of the priming translating into a measurable behavioural effect, as well as the possibility of observing a relationship between facial reactions and ratings. While we employed a short conscious imitation task before the main experiment in order to potentially increase prime sensitivity, it is not clear if this intervention had a tangible impact. In order to investigate the exact effect of such motor activations on bodily and behavioural priming, future studies could vary the presence or absence of an imitation task between participants. One potentially relevant difference between the current and previous GCC studies that found an behavorial priming effect (Kouider et al., 2011) concerns the placement and possible side-effects of the prime awareness trials (i.e. trials testing for prime awareness by asking people to try to classify the parafoveal expressions). Whereas previous studies presented these prime identification trials randomly interspersed with the main character rating trials, in the current experiment the awareness test was conducted in one block at the end of the procedure. Our priority in the present study was to optimise conditions for observing unconscious emotional facial activation. As such, we sought to minimise potential muscular interference. Since it has been shown that increased mental and/or physical effort can induce tension in facial muscles (Morree & Marcora, 2012; Topolinski & Strack, 2015), we wanted to avoid the possibility that participants’ ongoing effort to identify the prime face during the priming procedure could create additional muscle tension. We therefore chose to assess awareness in a separate block after trials involving EMG had been concluded. We believe this was the correct strategy given that our priority was the reliable measurement of facial activation. However, previous studies found increased nonconscious priming effects under conditions where the affective nature of the primes was emphasized (Eckstein & Perrig, 2007; Spruyt, De Houwer, Everaert, & Hermans, 2012). Being asked to identify the emotion of the facial expression on every trial during the rating task might have arguably a similar effect, and thus might help to facilitate the behavioural priming. Future experiments could directly probe the relevance of prime identification trials in nonconscious priming paradigms by varying their occurrence (intermixed with vs. after the character rating trials) as a between-subject factor.

To conclude, the results of the present study demonstrate for the first time that unconscious emotional facial activation can be induced by dynamic facial expressions presented outside of awareness using the GCC paradigm. Since dynamic aspects of naturally-occurring facial expressions can play an important role in their interpretation (cf. Krumhuber, Kappas, & Manstead, 2013), the demonstrated effectiveness of this paradigm presents the opportunity to explore the unconscious influences of expressions in a more ecologically valid manner that can include natural transitions between expressions. This could open new possibilities for research into the eliciting factors and consequences of spontaneous facial reactions. For example, it is still a matter of debate in how far spontaneous facial reactions are *valence-specific* (i.e. differentiate between positive and negative emotions), *emotion-specific* (i.e. differentiate between emotional displays of the same valence), or are influenced by automatic, non-emotional *motor mimicry* (cf. Hess & Fischer, 2013; Moody, McIntosh, Mann, & Weisser, 2007). Additionally, future research should establish under which conditions facial activation can affect subsequent behaviour.

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